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Modeling & Simulation of Distribution Grids

- Multi-agent based LFC for islanding operation

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Centre for Electric Technology (CET)
Technical University of Denmark (DTU)

June 21, 2012
@ Power Event

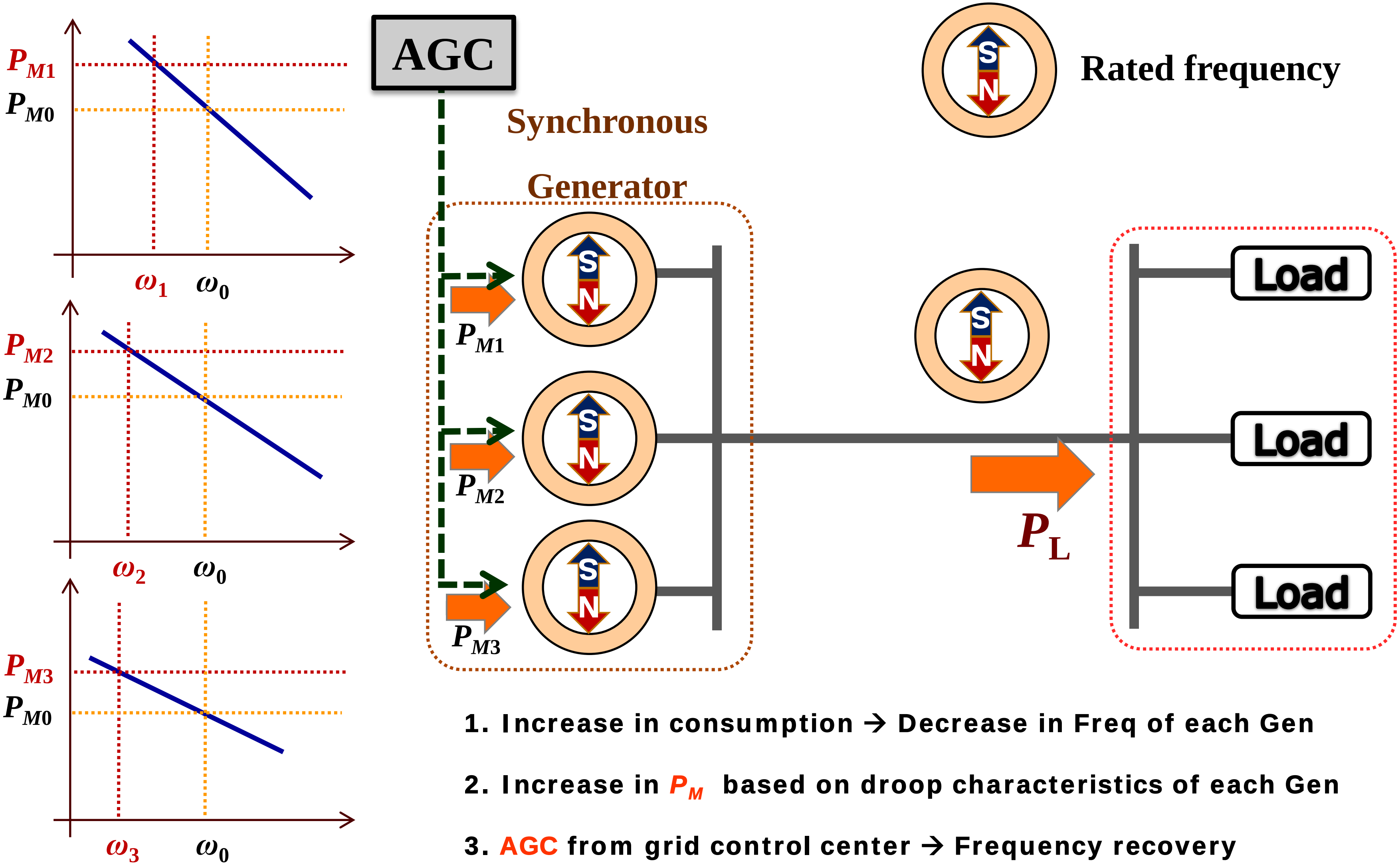
Outline

- Introduction
- Real time simulation platform
- Multi-agent based controller
- Description of test system
- Case study simulation results
- Conclusion

Introduction

- Distribution Generation(DG) source is gaining popularity and is ever increasing in importance
- DGs installed in the grid are gaining in complexity
- Specially, Islanded Distribution System
- Requires new forms of operation & develop sophisticated control strategies
- EMT simulation is now a common tool for power system engineers
- Real time simulators are more accessible than ever

Frequency control of generators



1. Increase in consumption → Decrease in Freq of each Gen
2. Increase in P_M based on droop characteristics of each Gen
3. AGC from grid control center → Frequency recovery

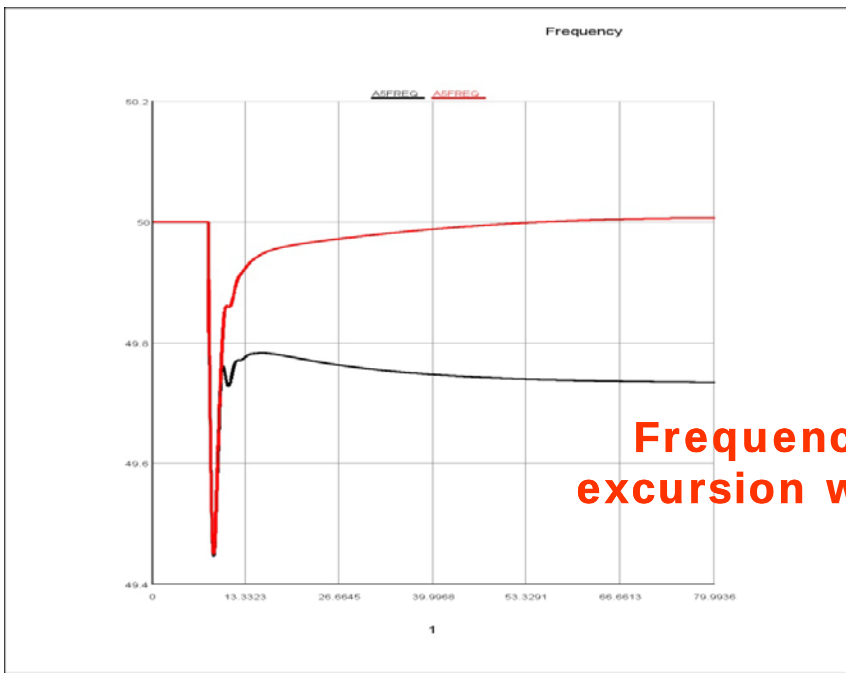
Source : WeGAT research center, Korea 2011

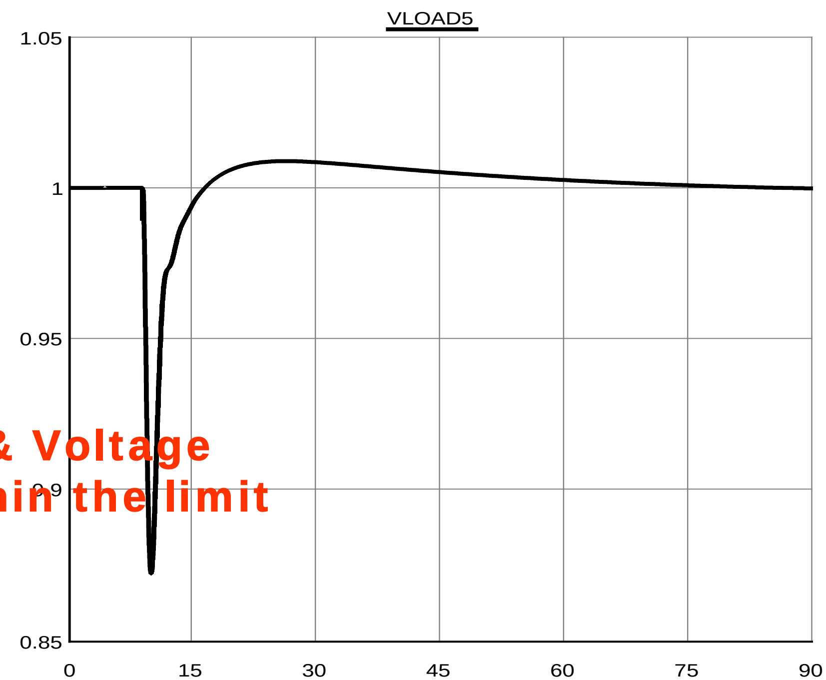
Partial Blackout (Sept 15, at 3pm, Korea)

- Due to the shortage of frequency reserves
- This could be easily prevented
- As a result, 17 employees were fired (4 Gov, 5 KEPCO, 8 KPX as of Sept 28)

Goal & Idea

- Develop a multi-agent based controller to stabilize the frequency and voltages of an active distribution network in the event of islanding operation





Frequency & Voltage excursion within the limit

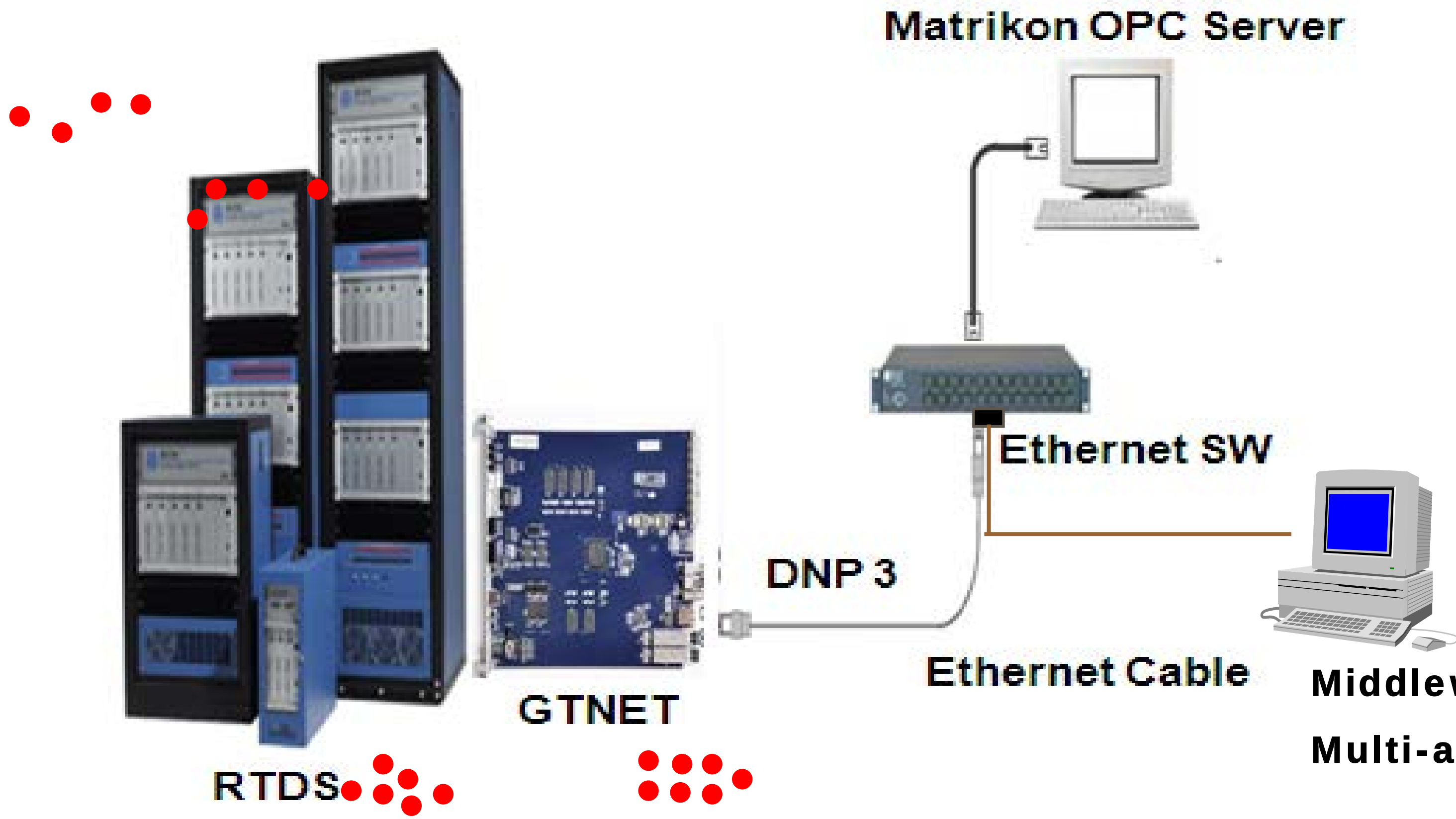
Real Time Simulation Platform

- RTDS is a power system simulator that solves electromagnetic transients in real time

What is *Real Time* Simulation:

- By using the RTDS Simulator, a system's response over 1 second is computed in ***exactly*** 1 second.
- For a given time step of say 50 microseconds, all calculations required to determine the power system's state are solved in precisely that amount of time. → Sustain real time operation

Real Time Simulation Platform (continue)



Middleware SW

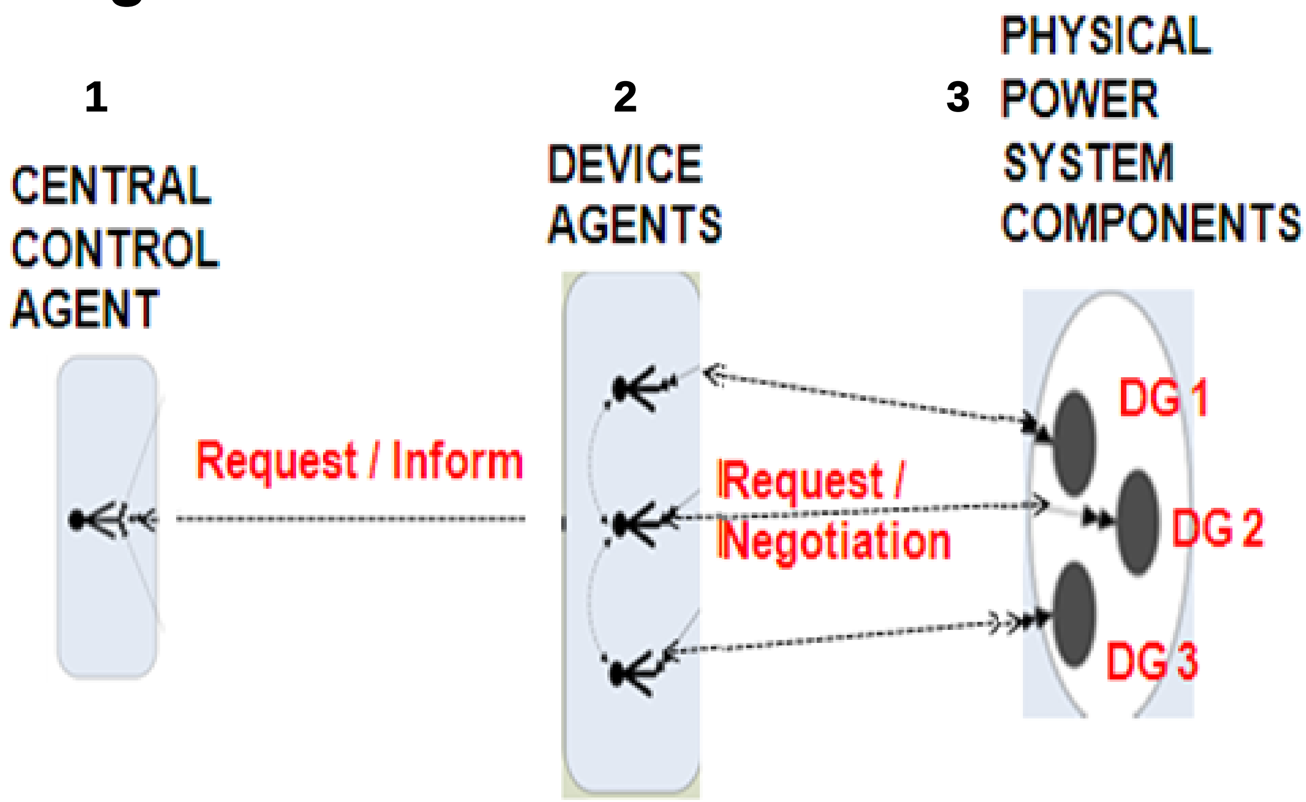
Multi-agent

Each agent creates its own connection and has an individual channel of control commands which ensures decentralized nature and robustness of the control

Multi Agent based Controller (3 layers)

- Central Control Agent is responsible for controlling & managing the grid.
- Device Agent interact directly with the physical power system components and performs control functions.
  - Generator agent (P, Q set point)
  - Breaker agent (open & close)
- Physical power system components are DGs, loads, lines, etc. These agents have fixed data such as
  - Unit names, min & max power, fuel cost coefficient
  - Current power production & status of the unit

Multi Agent based Controller - Architecture

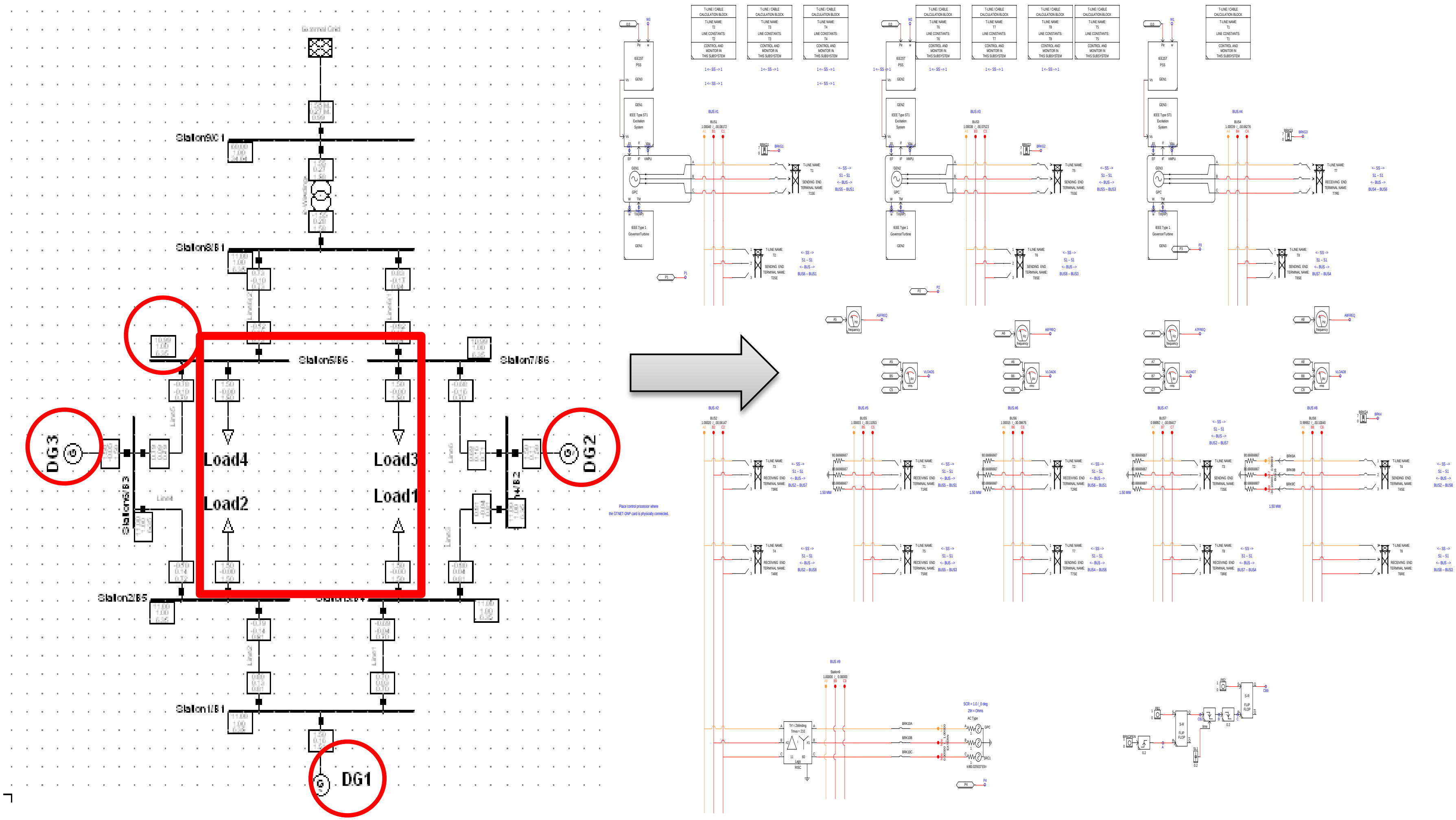


DG agent calculates its cost function based upon its current state, and sends a bid…cumulates…which DG agent shall provide regulation service and how much power should be delivered !!

Modified IEEE 9-bus Test System

- The modified IEEE 9-bus system comprises a 60kV, 50Hz grid which feeds an 10kV network through a 60/10 kV transformer.
  - 3 DG units (1.5 MW, Bus 1,3,4)
  - 8 T/L
  - 1 TR
  - 4 Loads (6 MW, Bus 5 - 8)
  - Battery Energy Storage System (BESS)

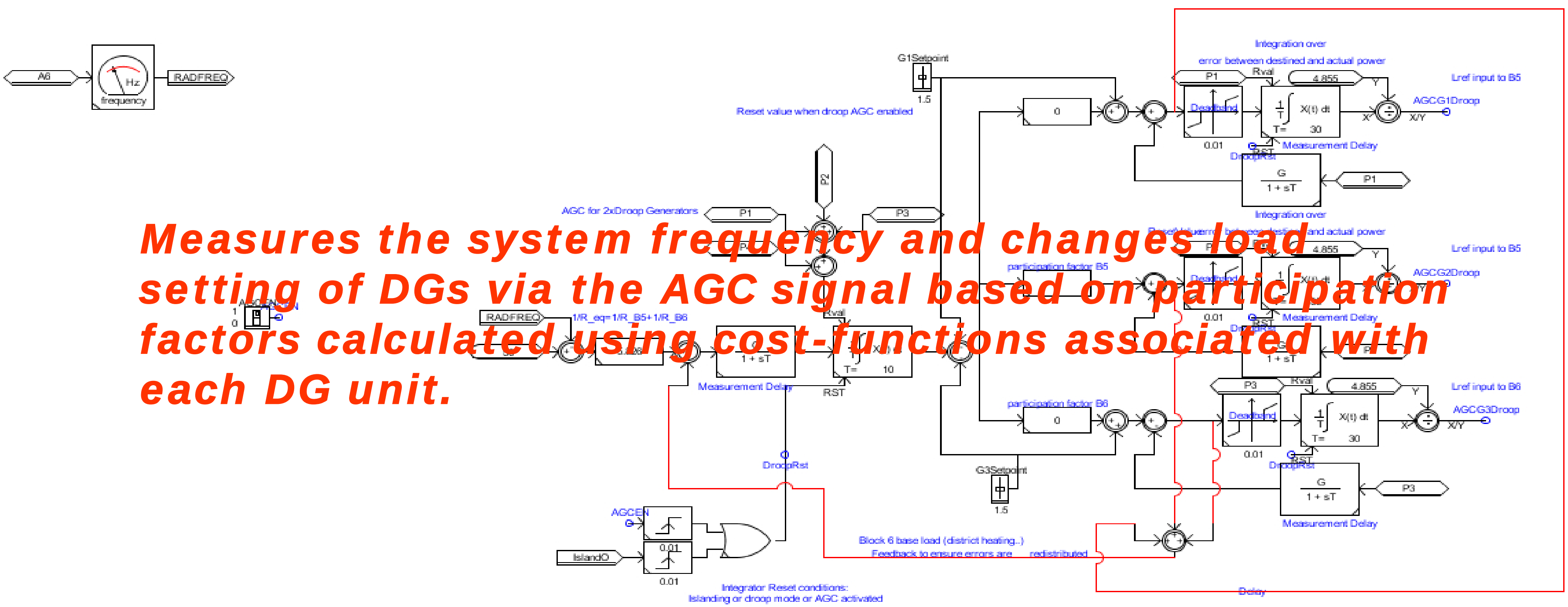
Modified IEEE 9-bus Test System (continue)



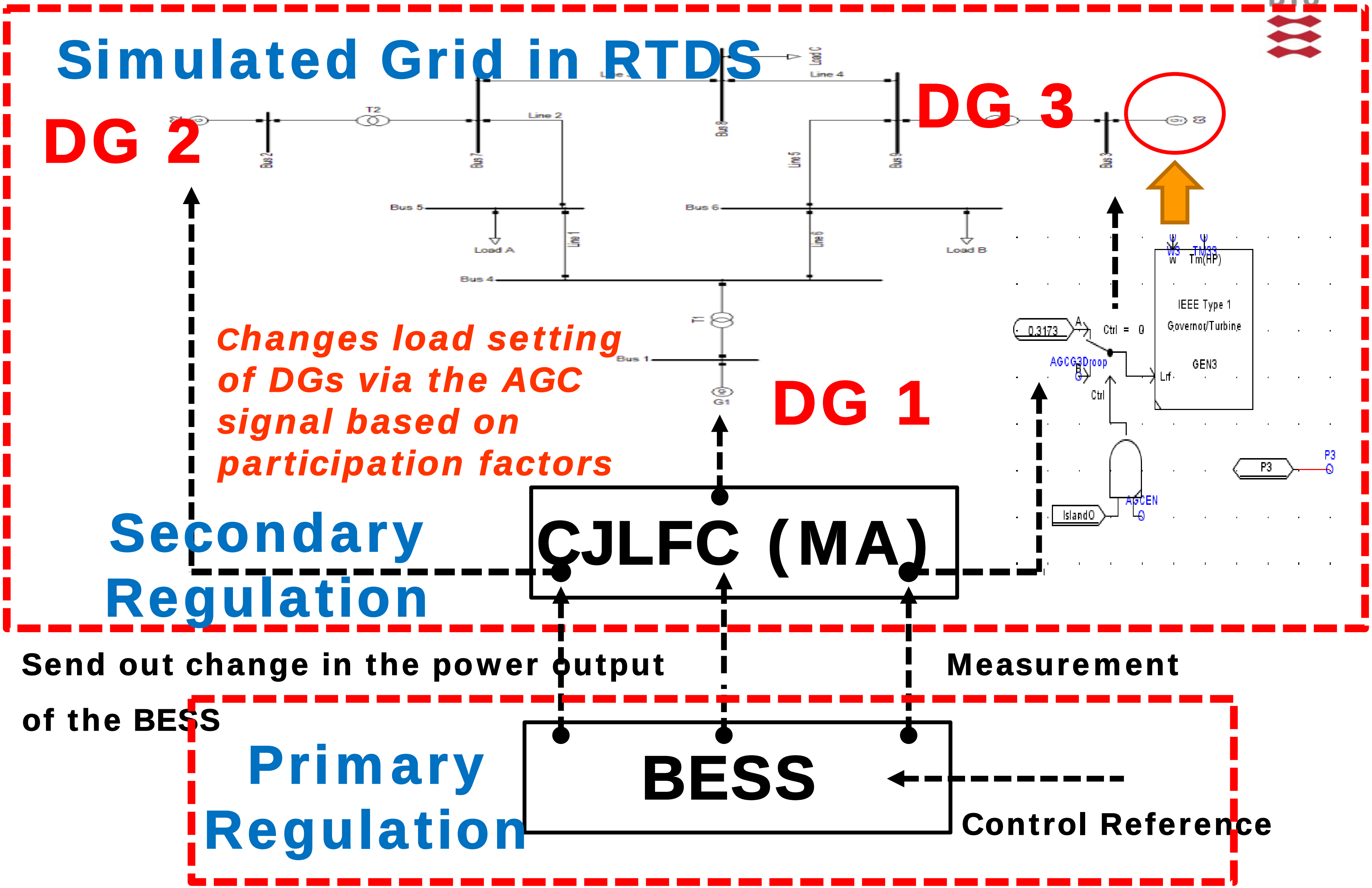
Modified IEEE 9-bus Test System (continue)

- Intelligent controller : Reacts to respond quickly to the frequency deviation in the event of islanding situation (LFC scheme to control the speed of DGs)

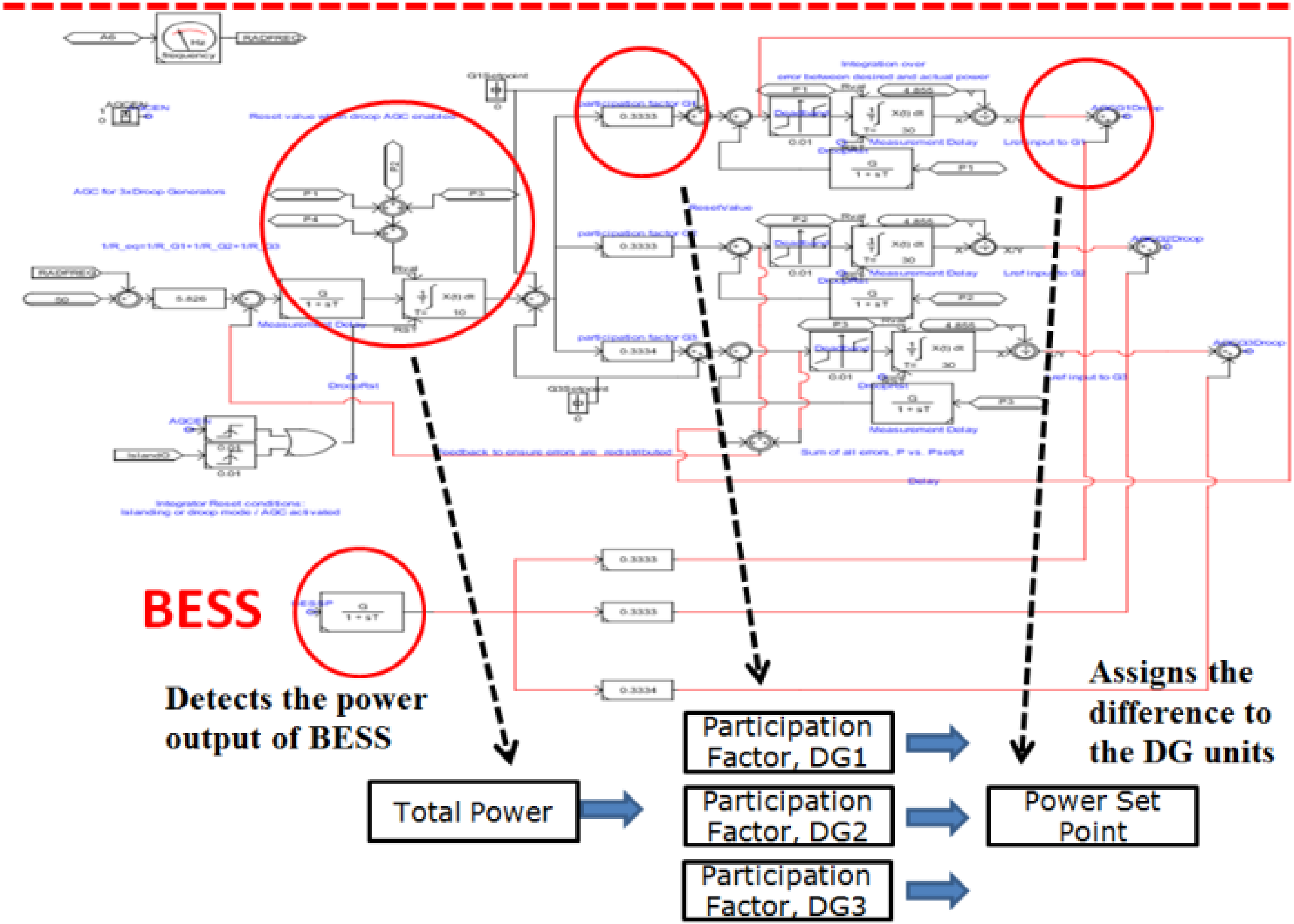
hmMod-Script



Measures the system frequency and changes load setting of DGs via the AGC signal based on participation factors calculated using cost-functions associated with each DG unit.



Simulated Grid in RTDS
DG 2
DG 3
DG 1
Load C
Line 4
T2
Line 2
Bus 5
Load A
Bus 6
Load B
Bus 4
Bus 1
G1
IEEE Type 1
Governor/Turbine
GEN3
Ctrl = 0
0.3173
AGCG3Droop
Ctrl
IslandO
AGCEN
P3
Changes load setting of DGs via the AGC signal based on participation factors
Secondary Regulation
CJLFC (MA)
Send out change in the power output of the BESS
Measurement
Primary Regulation
BESS
Control Reference



Centralized Joint Load Frequency Control

Simulation of Islanding Operation

Case I

Step1. Loss of 1.5 MW power from the grid due to an outage or intentional islanding

Step2. Created an imbalance in the islanded part of the network

Step3. Load agents observe voltage & frequency drop

Step4. Load agents contact DF agent for any available regulation service

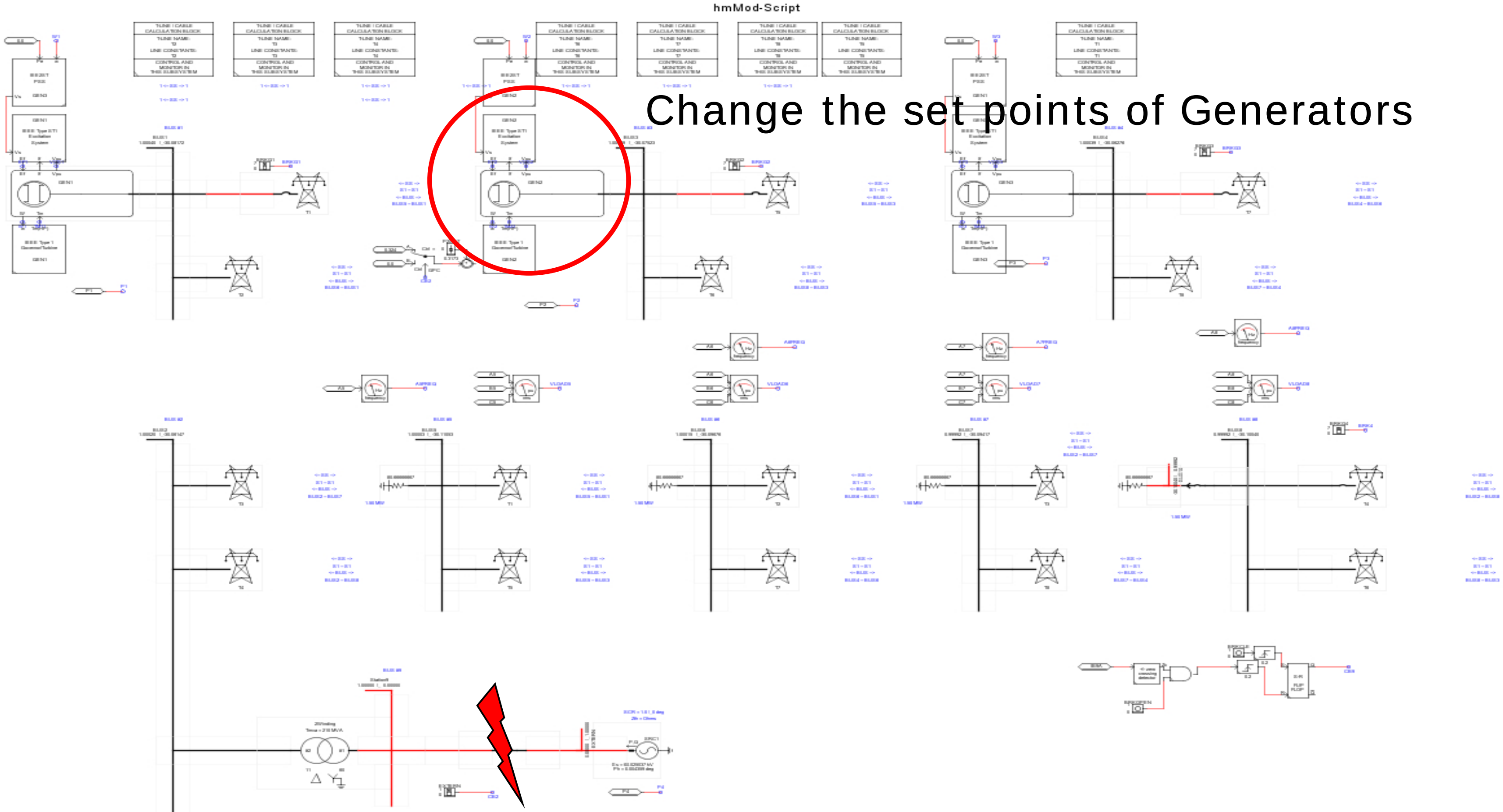
Step5. DF agents informs the current service availability and provides its reference (i.e P_Gen2=0.6415)

Step6. Load agents request DG #2 agent for provision of service

Step7. DG #2 agent accepts the request and provides the service by increasing its active power set point

Step 8. Voltage & frequency recover at the nodes of all loads

Case I

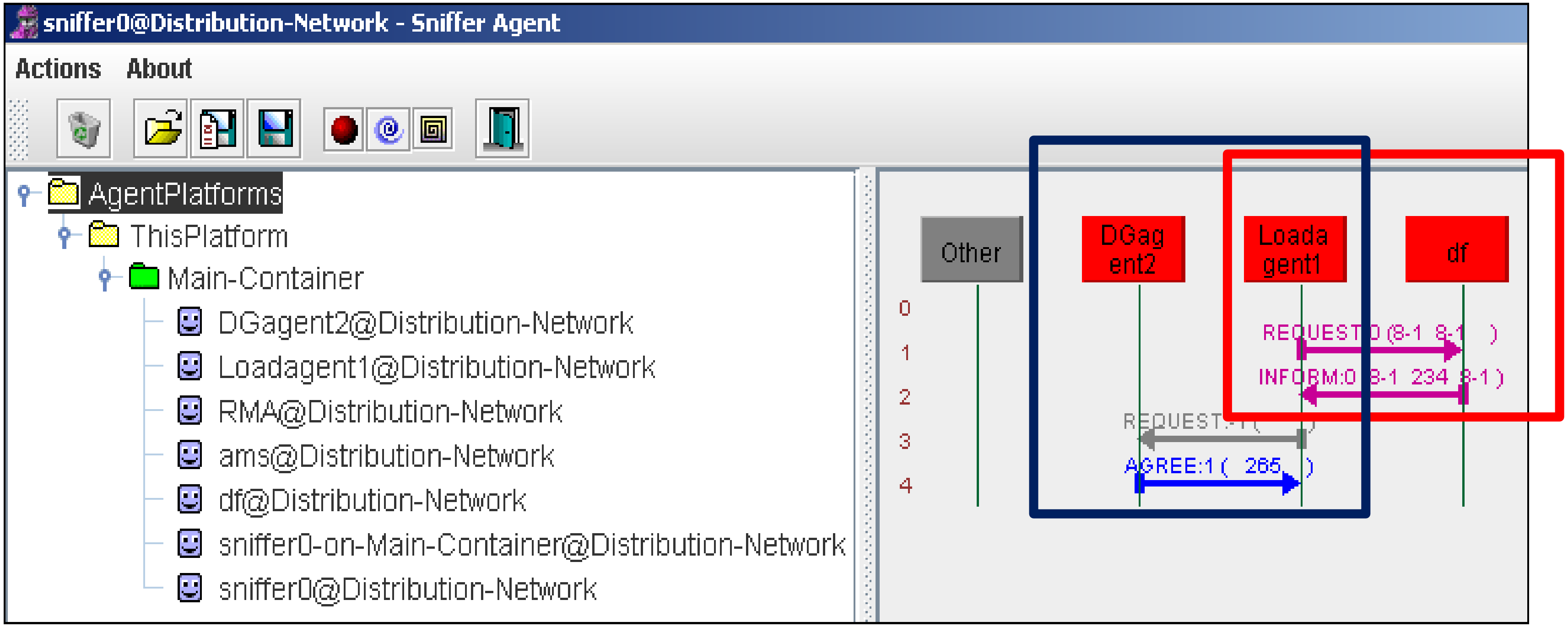


Change the set points of Generators

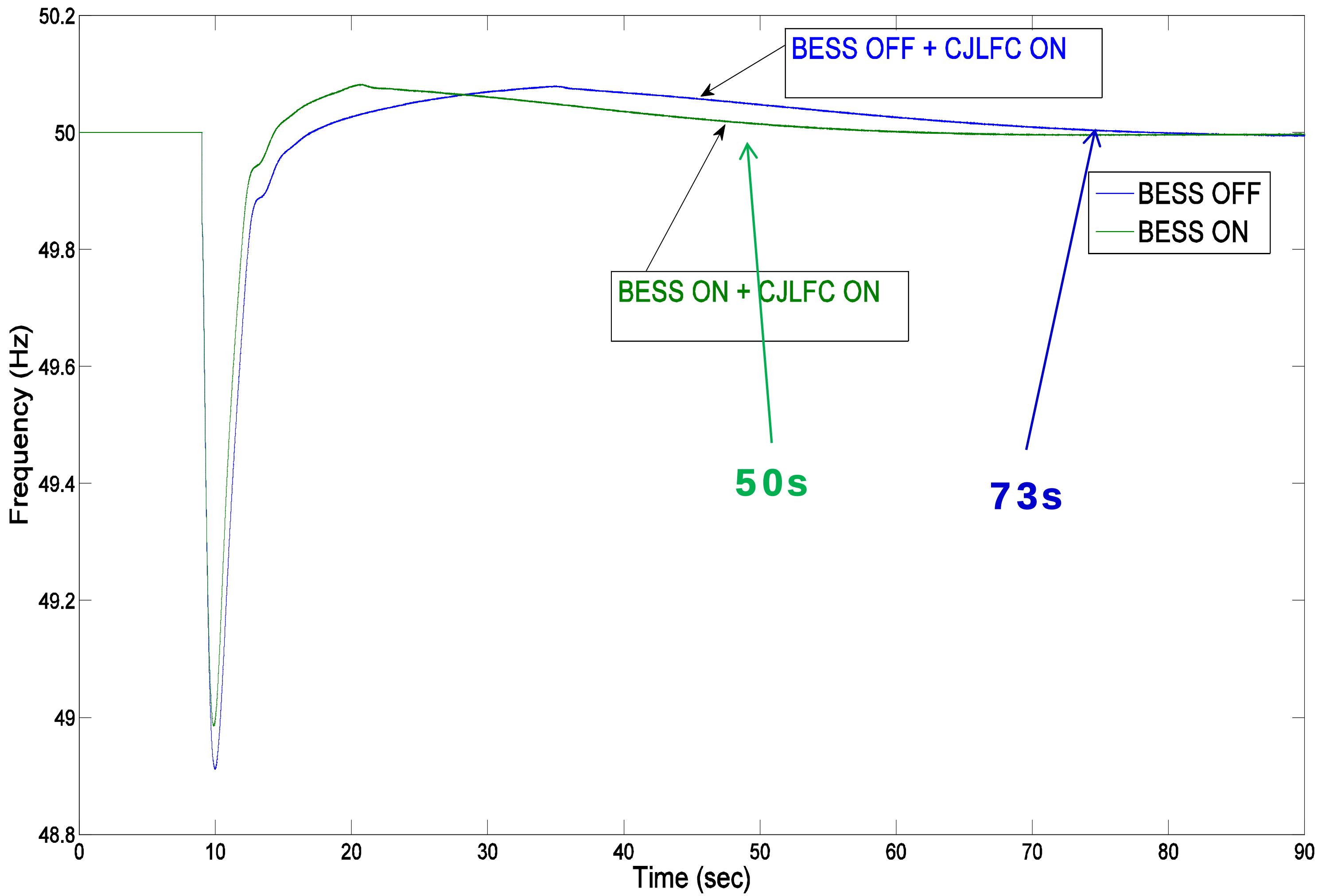
Case 1 – External source disconnected

Simulation Results

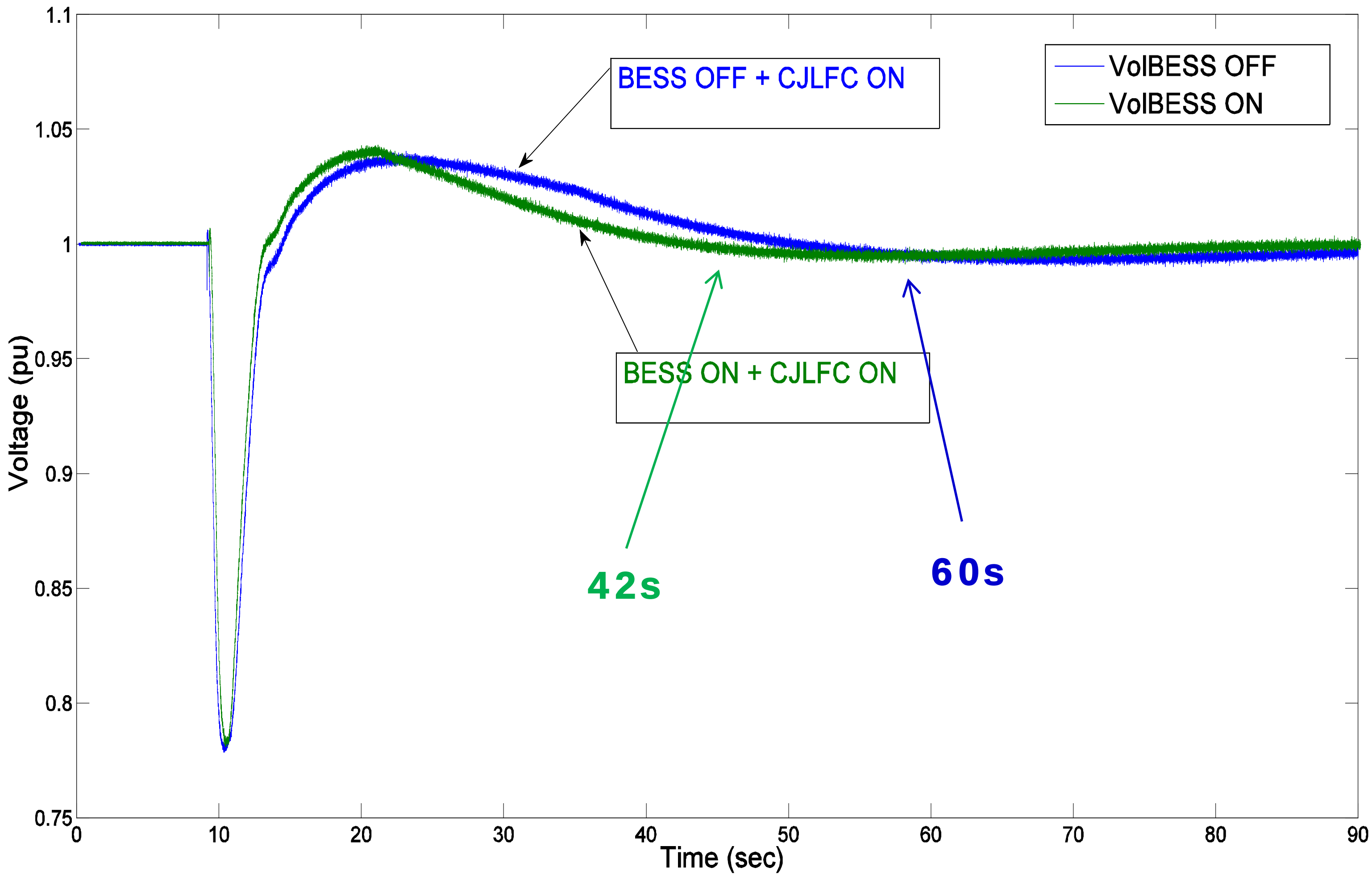
Case I

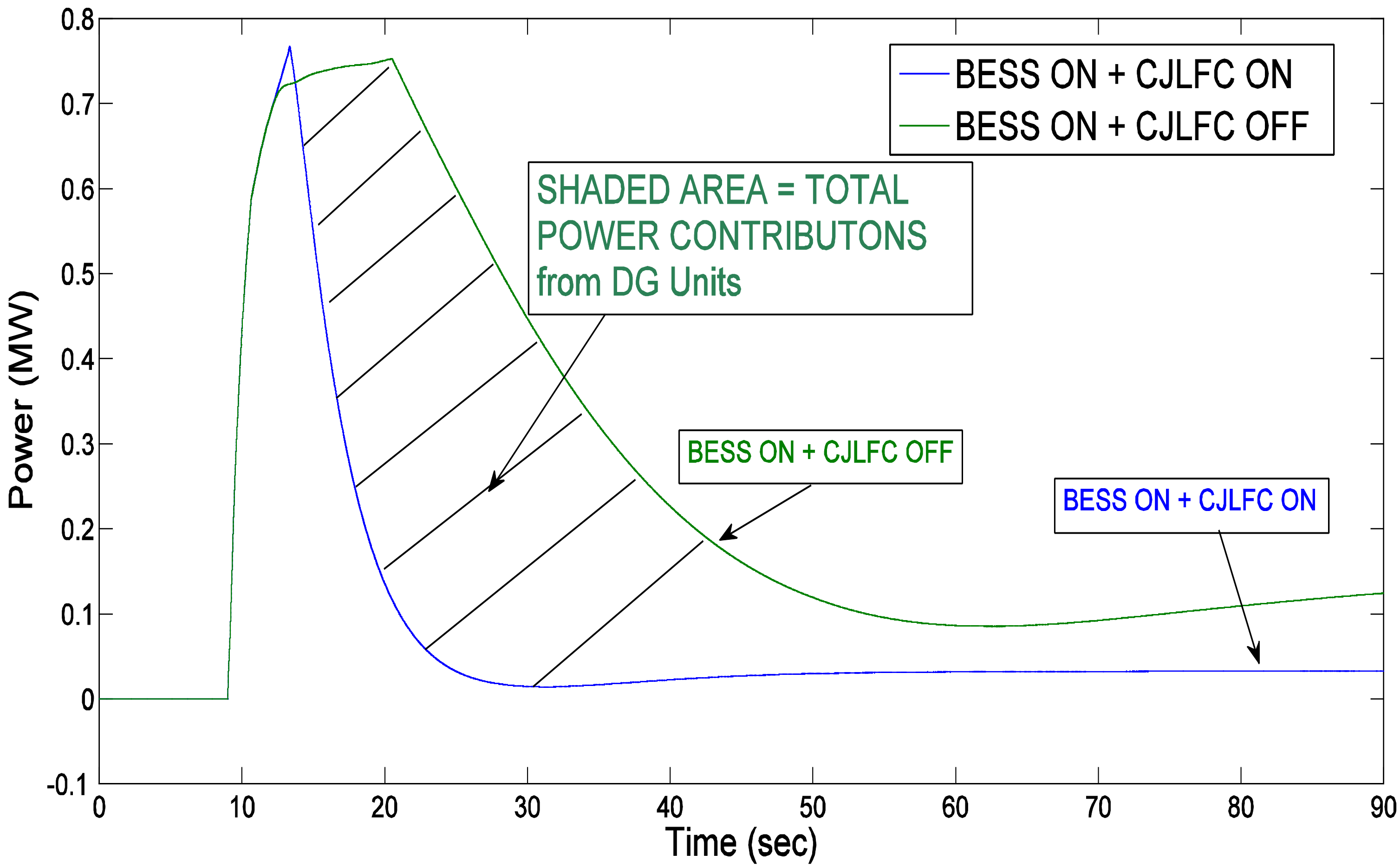


The MA controller was capable of bring back the frequency to 50Hz and restored at about 50 s.

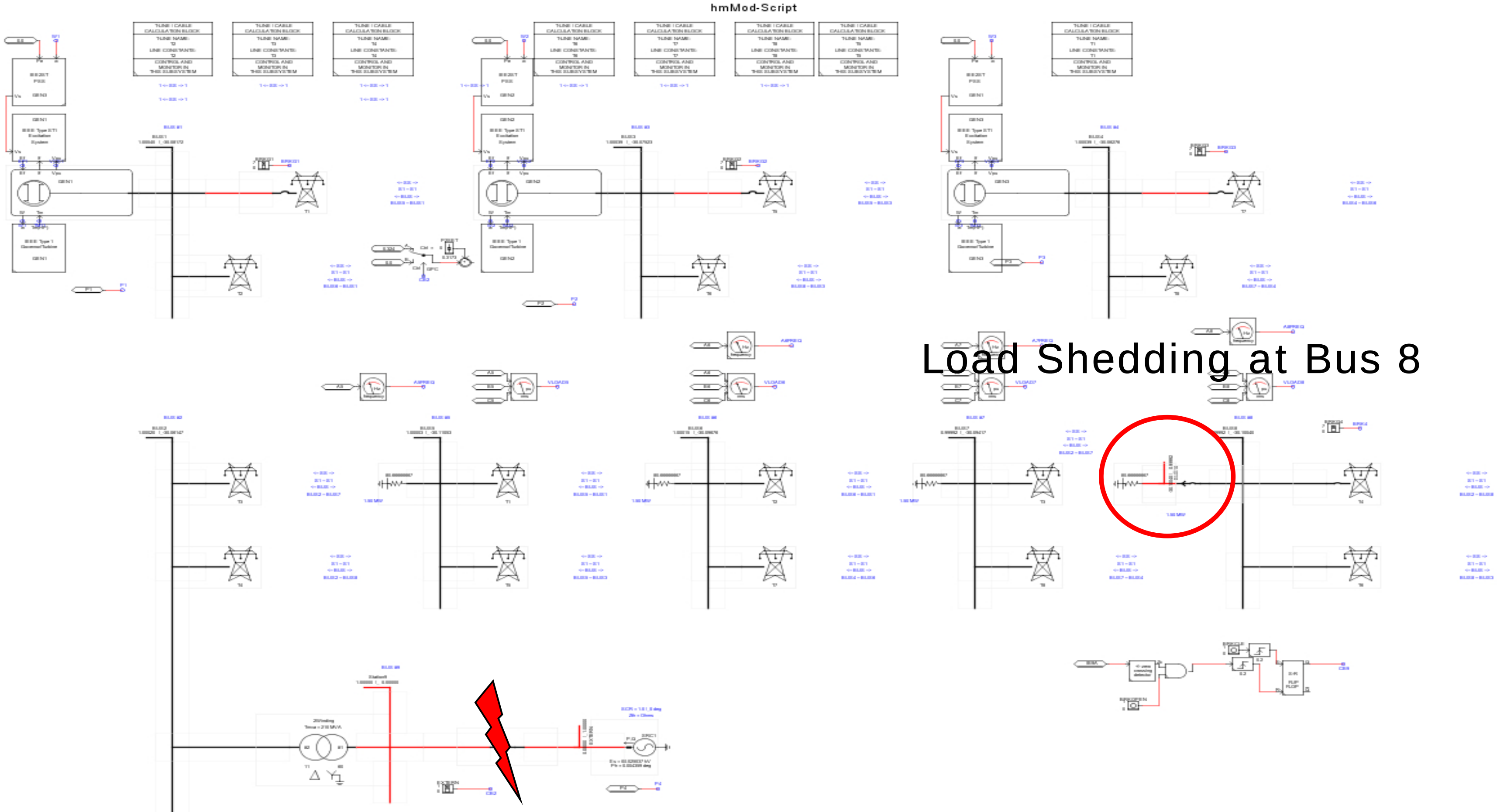


The MA controller was also capable of reducing the voltage deviations and keeping them within the permissible limits.




BESS ON + CJLFC ON
BESS ON + CJLFC OFF
SHADED AREA = TOTAL POWER CONTRIBUTONS from DG Units
BESS ON + CJLFC OFF
BESS ON + CJLFC ON
Power (MW)
Time (sec)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
10
20
30
40
50
60
70
80
90

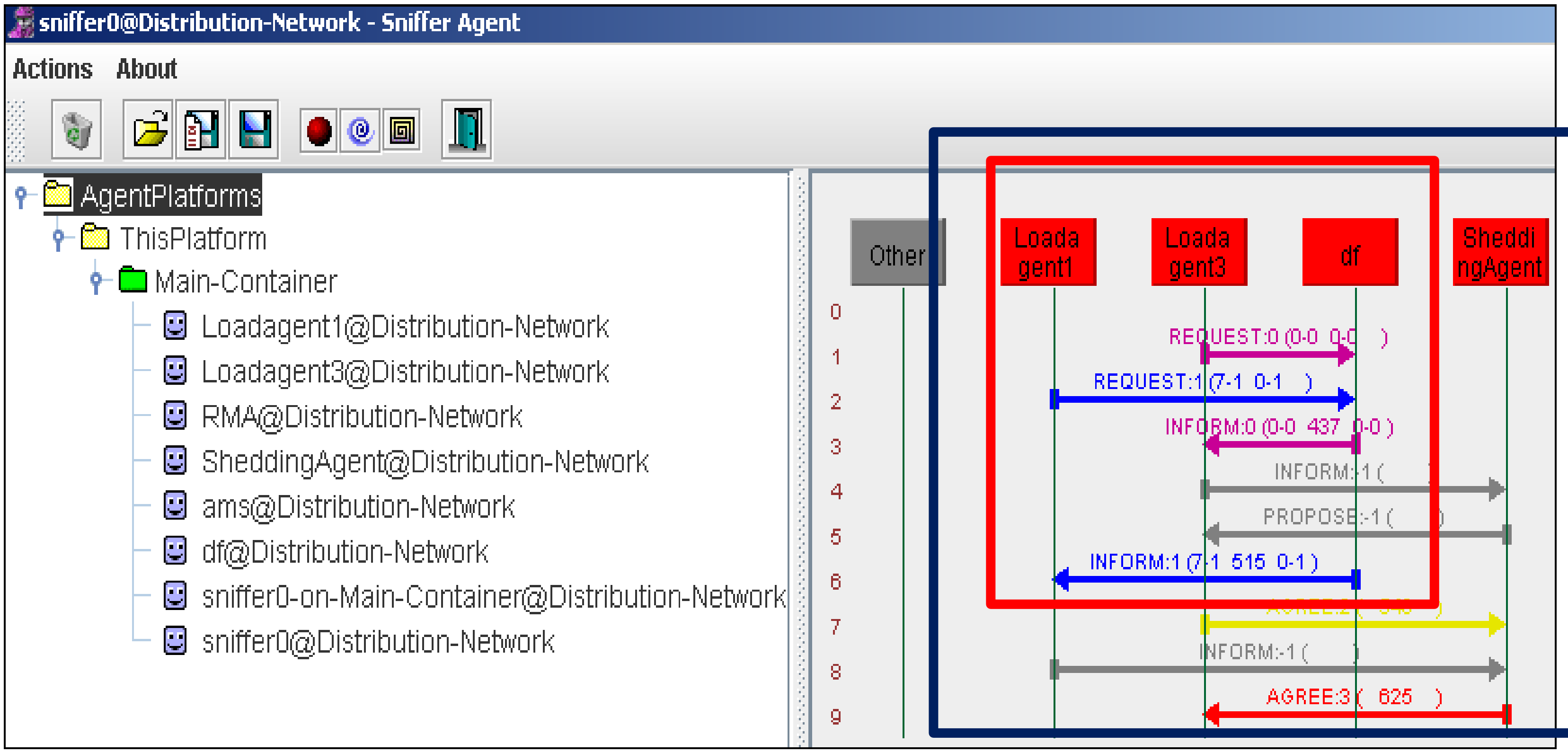
Case II

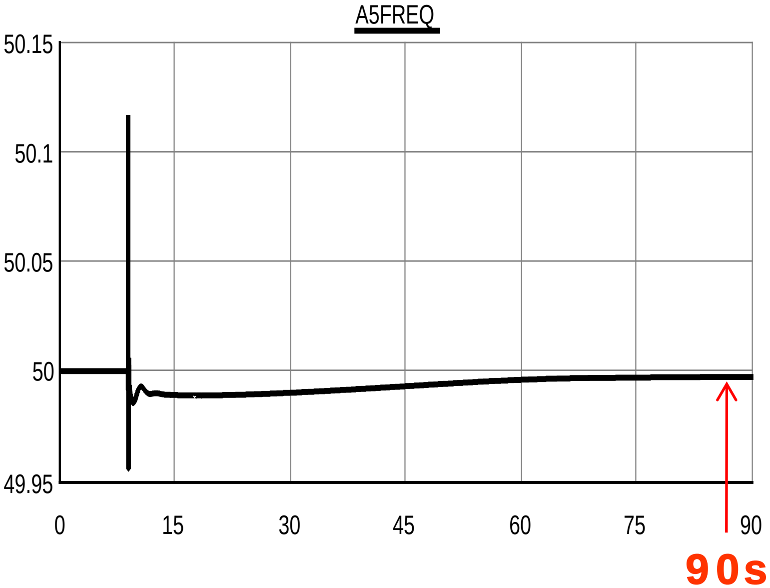


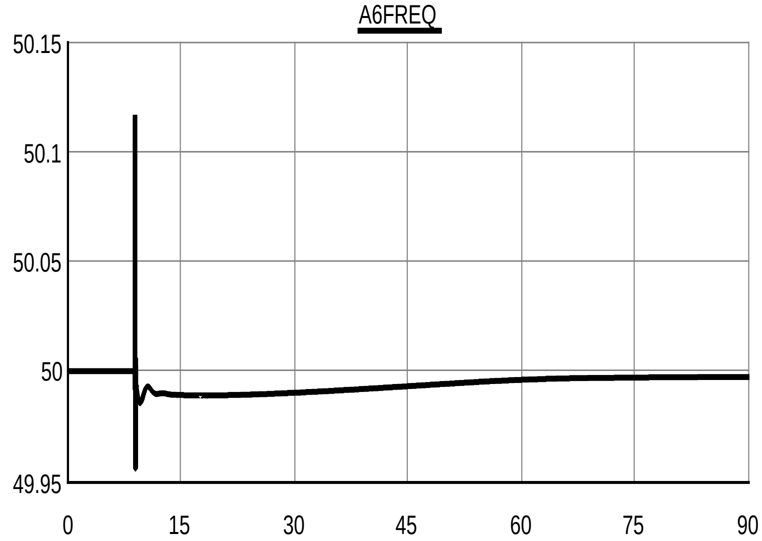
Case 2 – External source disconnected

Simulation Results

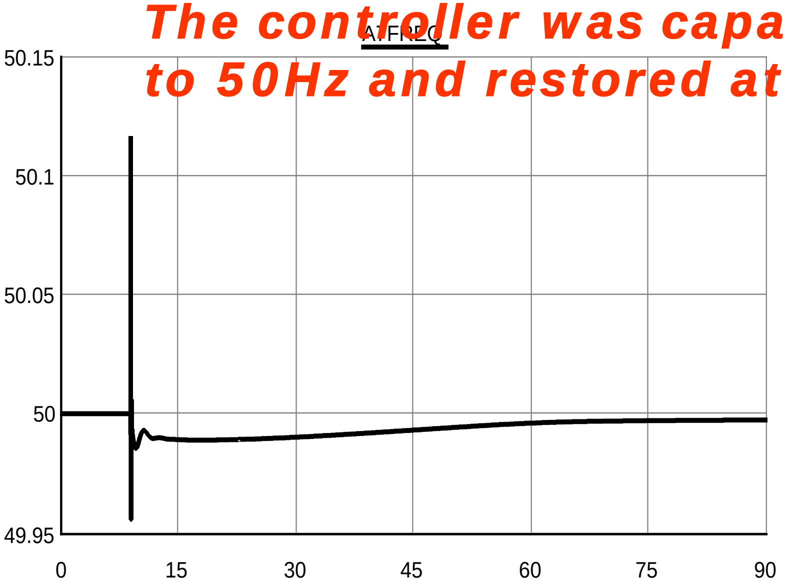
Case II

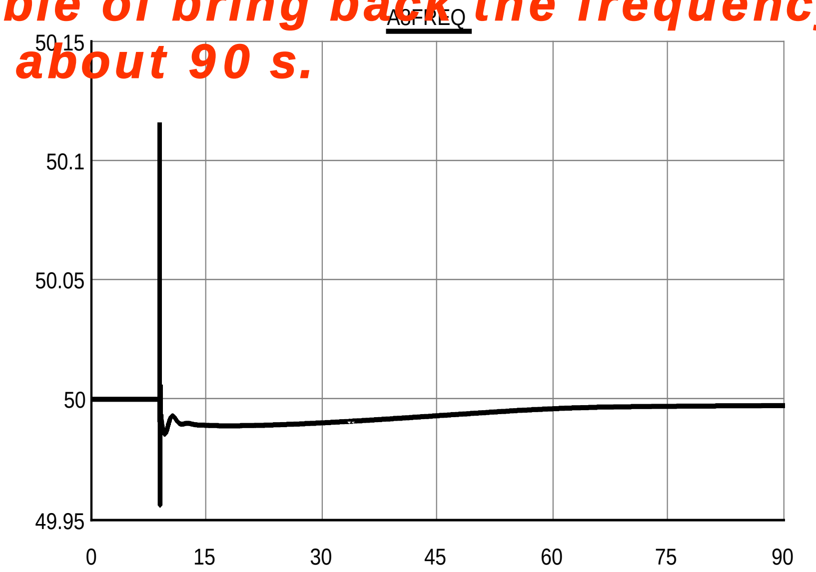


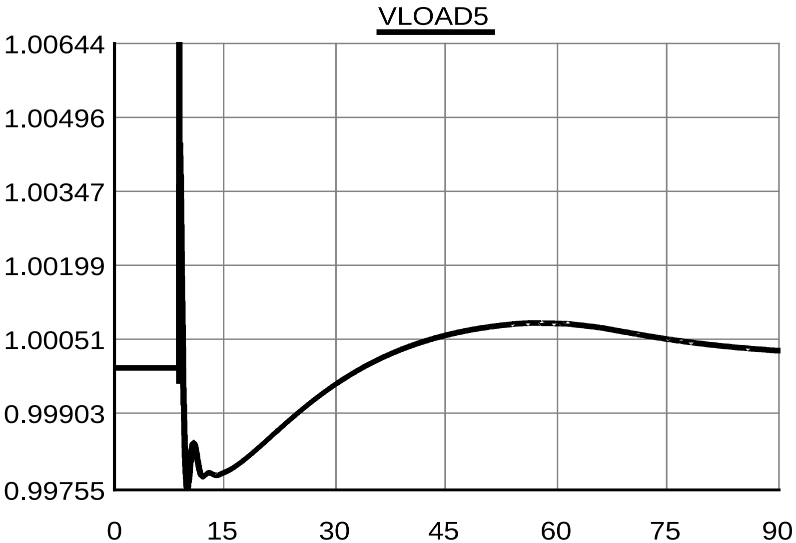


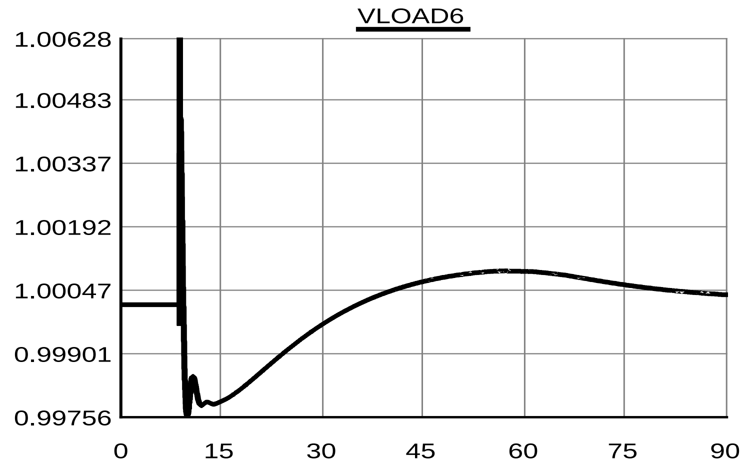


The controller was capable of bring back the frequency to 50Hz and restored at about 90 s.

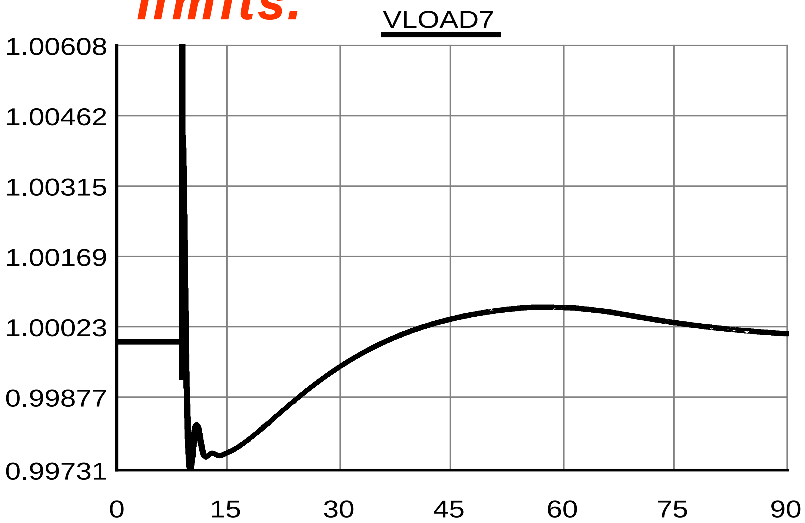


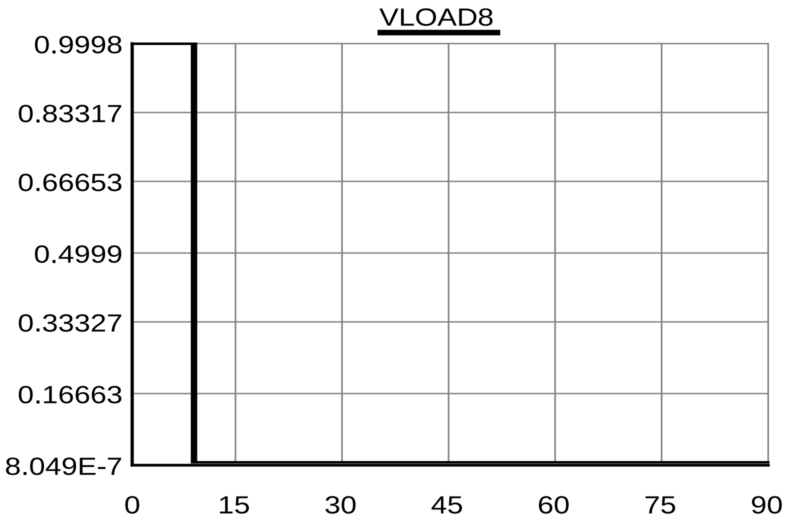


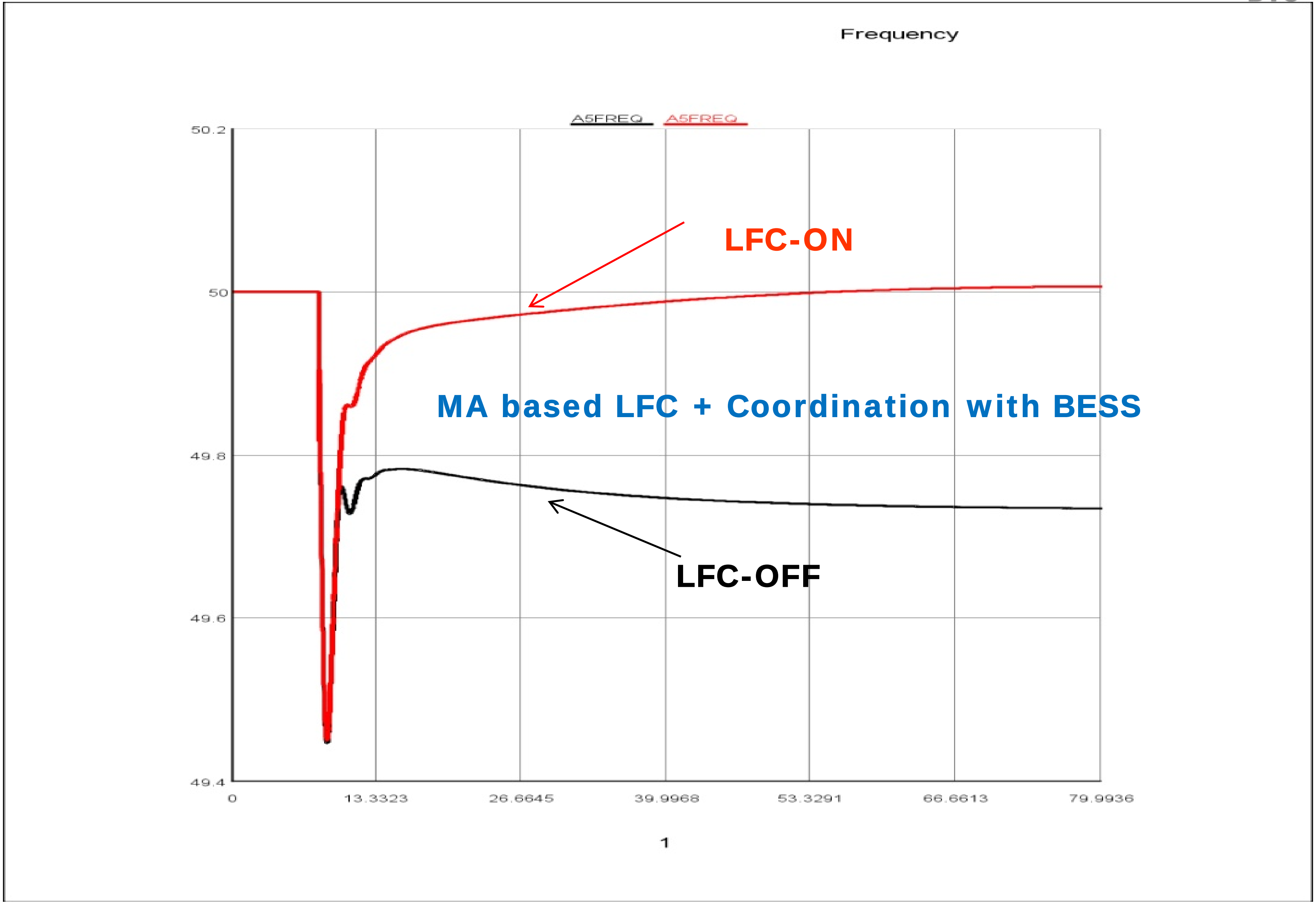




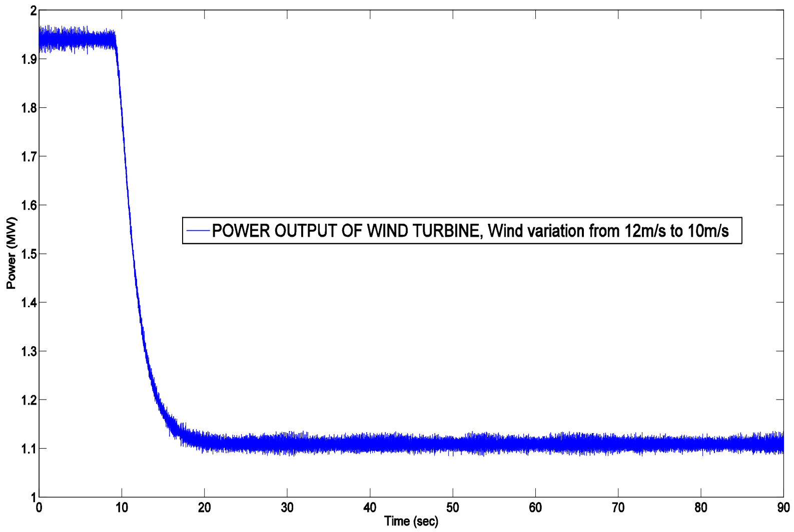
The controller was also capable of reducing the voltage deviations and keeping them within the permissible limits.

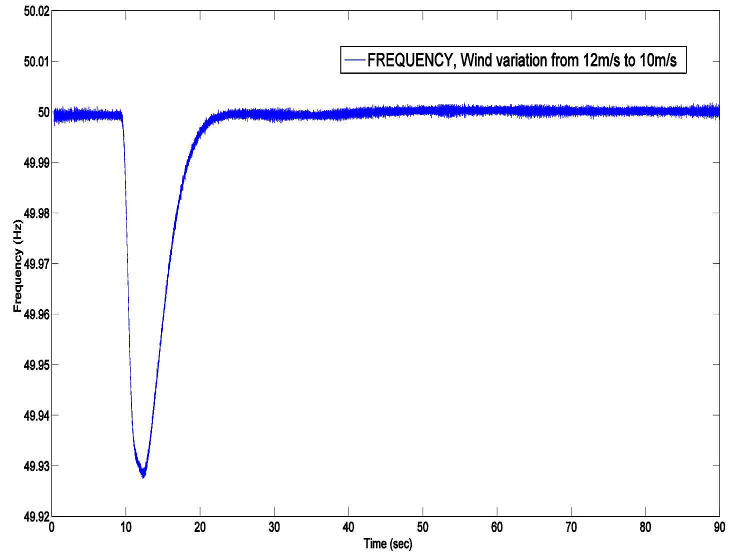


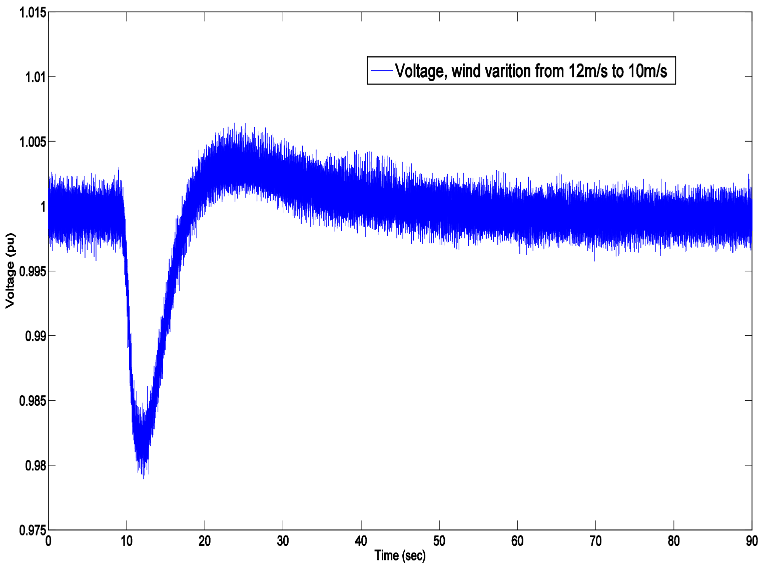


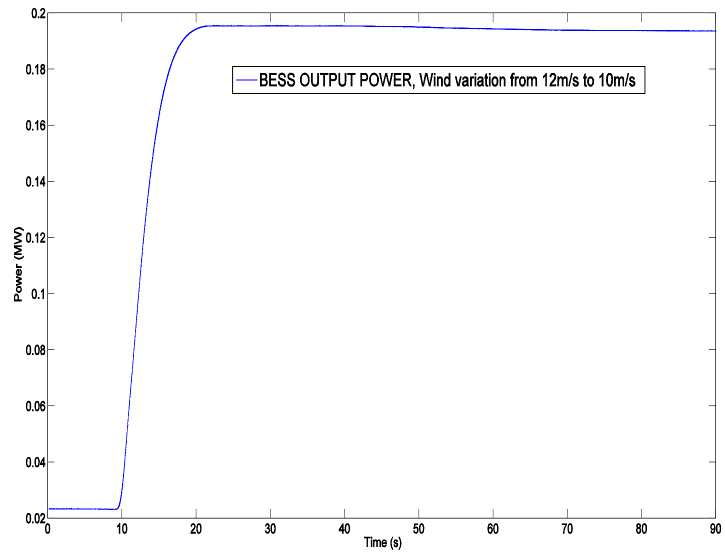

Frequency
A5FREQ
A5FREQ
50.2
50
49.8
49.6
49.4
0
13.3323
26.6645
39.9968
53.3291
66.6613
79.9936
1
LFC-ON
MA based LFC + Coordination with BESS
LFC-OFF

Wind Speed Variation from 12m/s to 10m/s









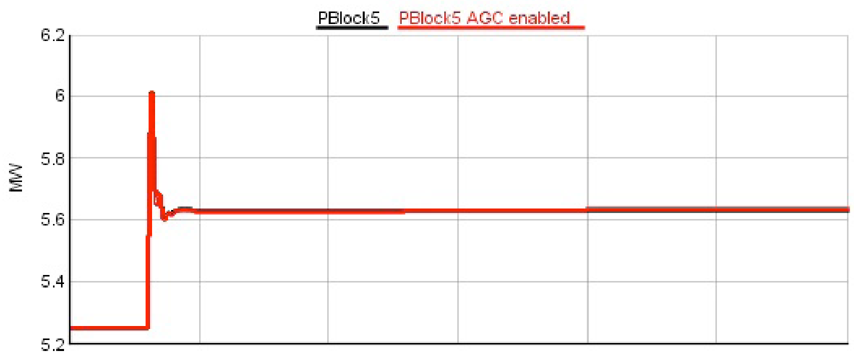
Conclusions

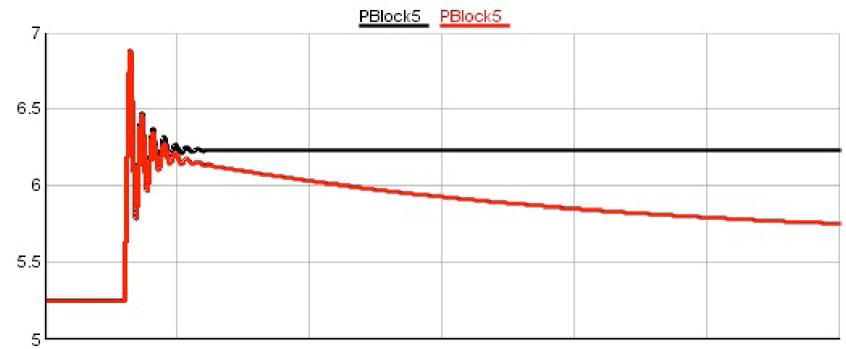
- A multi-agent based controller for islanding operation of active distribution system has been proposed to help stabilize the frequency & voltage
- The proposed contoller can respond to the islanding situation fast and efficiently stabilize the frequency & voltage with a coordination of BESS under contingency
- However, there are a number of challenges
- Multi-set of DG units & loads, coordination strategies, and scalability
- SOC control scheme for energy storage

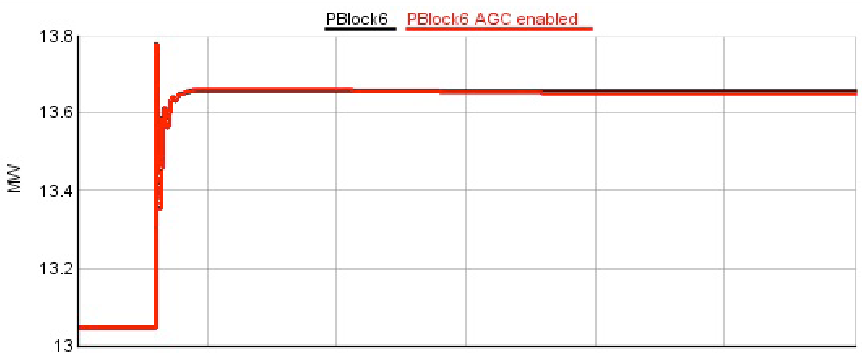
- CONTRIBUTOR : Qiuwei, Arshad, Haoran, Christian, Jacob

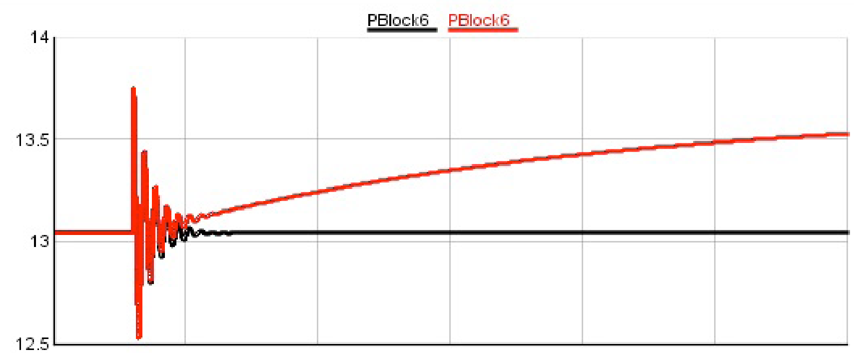
Bornholm Power System

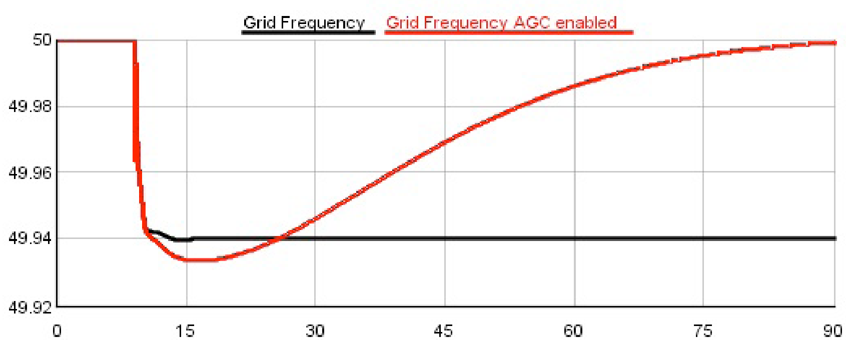
- The Bornholm power system comprises a 60kV, 50Hz grid which feeds an 10kV network through a 60/10kV transformer.
  - Peak Load : 63 MW
  - 18 Substations
  - AC submarine cable connection to Sweden
  - 44 Transformers
  - Unit 5 : 25 MW
  - Unit 6 : 37.5 MW CHP
  - Wind, Biogas, Diesels (67 MW)
  - BESS

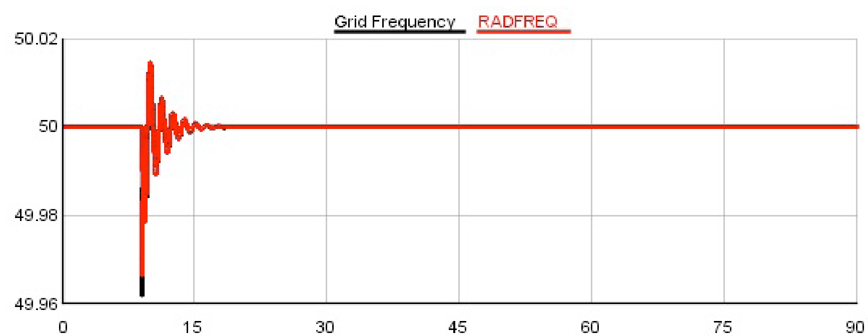

PBlock5
PBlock5 AGC enabled
MW
6.2
6
5.8
5.6
5.4
5.2


PBlock5
PBlock5
7
6.5
6
5.5
5


PBlock6
PBlock6 AGC enabled
MW
13.8
13.6
13.4
13.2
13


PBlock6
PBlock6
14
13.5
13
12.5


Grid Frequency
Grid Frequency AGC enabled
50
49.98
49.96
49.94
49.92
0
15
30
45
60
75
90


Grid Frequency
RADFREQ
50.02
50
49.98
49.96
0
15
30
45
60
75
90

- To accomodate more wind power and 400 V grid
- Development of Generic Model of Bornholm Power System → Danish Benchmark (similar to IEEE benchmark) for publicly available (ISGT 2012)
- PSO Optimization for BESS controller
- Implementation of IEC Generic Wind Turbine Modelling (Type 1A/B, Type 3)